

INTRODUCTION

Parameters of vegetation spatial structure are important factors having effect on the carbon cycle and the biodiversity of ecosystems. Retrieval of above-ground biomass remains a challenging task, especially in those areas with complex forest stand structure and environmental conditions. Therefore, how to estimate biomass more accurately is still a problem need to be worked out urgently. Because of the penetration capability and sensitive to the water content in vegetation, radar is naturally a facility that can be used to detect spatial structure and aboveground biomass of vegetation canopies.

NASA/JPL's Uninhabited Aerial Synthetic Aperture Radar (UAVSAR) provides high-resolution polarimetric SAR data for use in multiple studies including the retrieval of forest structure parameters. As other airborne SARs, one disadvantage of UAVSAR image data is the large range of local incidence angles across the image (about 40 degrees in our data). Along the range line, radiometric distortion due to the illumination area is a function of the local incidence angle θ_0 . In order to correct this distortion, several studies had been taken.

As mentioned above, most studies focused on classification of land cover types, and didn't give enough attention on local incidence angle correction. This paper will discuss different correction methods and build a relationship between backscattering coefficient and local incidence angle, estimate aboveground biomass by using the corrected backscattering coefficient.

DATA AND TEST SITES

Test Sites

Our test sites are in Maine. One site is the Northern Experimental Forest (NEF), Howland (45.25°N, 68.75°W). The other site is Penobscot Experimental Forest (44.8°N, 68.6°W). About 20 persons spent two weeks measuring 24 plots (50m by 200 m per plot, divided into sixteen 25m by 25m subplots) in these two sites funded by the NASA-GSFC DESDynI-LIDAR Development Team. The direction of the 200m side is aligned with the range direction of the UAVSAR flight lines. The DBH (Diameter at breast height) of all live/dead trees with a DBH ≥ 10 cm and the height of the three highest trees in each subplot were recorded. Trees with a DBH < 10 cm were counted within a 2m wide transect in the center of the plot, and tallying stems by subplot and size class. The above-ground biomass was calculated using allometric equations.



SAR data

UAVSAR, a reconfigurable, polarimetric L-band synthetic aperture radar (SAR), is specifically designed to acquire airborne repeat track SAR data for differential interferometric measurements (<http://uavsar.jpl.nasa.gov/>). It provides high resolution polarimetric SAR data for use on multiple studies, such as retrieval of forest structure parameters. In this paper, one UAVSAR dataset acquired on Aug. 5, 2009 (013_090805, showed in Figure 1) was selected to estimate the relationship between backscattering coefficients and local incidence angles and to generate a correction equation, and it would be used to estimate above-ground biomass in forest.

Optical and other auxiliary data

Landsat/ETM+ image data and National Land Cover dataset (NLCD 2001) were used to classify the forest types. In this paper, we tried to divide the forest by three types, i.e. the Deciduous Forest (DF), Evergreen Forest (EF), and Mixed Forest (MF). ETM+ image was acquired on Aug. 28, 2009 since UAVSAR data we used in this paper was acquired on Aug. 5, 2009. This ensures the land cover type be same in both datasets. Before classification, ETM+ data were radiometrically corrected. Assuming that forest types wouldn't be changed without disturbance within few years, especially in the boreal forest area, forest types were extracted from auxiliary data NLCD 2001 for training data. ENVI/Decision Tree method was used to classify the ETM+ image.

METHODS

Sun et al. developed a model-based slope correction to reduce the topographic effect. By referring to this research, we made a regression between original backscattering coefficient and local incidence angle. Since the study sites are flat, we assumed that incidence angle calculated from UAVSAR metadata was the local incidence angle, although there are some rough areas in southern part of UAVSAR image. This assumption could be true because the field plots are in the flat area. The algorithms for incidence angle correction were developed using the SAR and forest classification data from the flat areas. Only the areas classified as forest types (DF, EF and MF) in the image were selected to analysis the relation between uncorrected backscattering coefficient in different polarizations and local incidence angle. The VV polarization was not used due to its poor relationship with above-ground biomass. Analyses were focused on two polarizations, HH and HV. For each of the forest types, relations between uncorrected data and local incidence angle was shown in Figure 2.

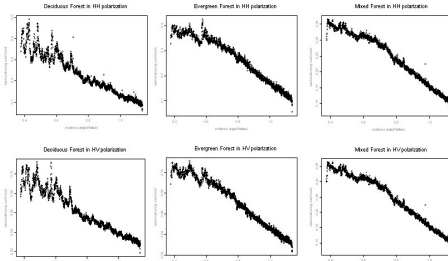


Fig. 2 (left to right: DF, EF and MF for relation between uncorrected and incidence angle two polarizations)

A simple model was used to describe the relations between and is described as following equation,

$$\sigma^0 = \sigma^0_{\text{corr}} \cdot \cos^n \theta \quad (1)$$

Where σ^0 is the backscattering coefficient when θ is zero, and θ is the local incidence angle. The power n ranges from 1 to 2. If θ is the incidence angle at the center of the image, the following equation can be used to make the incidence angle correction after the n is determined from fitting the equation (1) using SAR data,

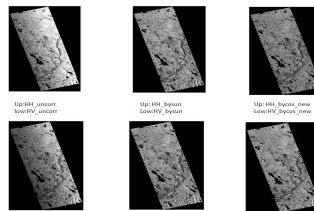
$$\sigma^0_{\text{corr}} = \sigma^0 \cdot \left[\frac{\cos \theta_0}{\cos \theta} \right]^n \quad (2)$$

RESULTS

The values of n and the R^2 of the fitting Equation (1) using the data shown in Fig. 1 for HH and HV polarizations are listed in Table 1.

Table 1			
	DF	EF	MF
HH	1.8564	1.7126	1.6573
R^2	0.9662	0.9808	0.9896
	DF	EF	MF
HV	1.5417	1.6070	1.4653
R^2	0.9617	0.9875	0.9919

Using the n values from Table 1 in Equation (2) the radiometric distortion was corrected for pixels of three forest types. Pixels belonging to other land cover types in the UAVSAR datasets were corrected using equations in reference. Fig. 3 shows the UAVSAR data before and after the angle correction.



The field data allow for analyses in different scales, such as 25m by 25m, 50m by 50m, and 1ha. Mean backscattering coefficient value in 24 field plots (384 sub-plots) for different scales were extracted by ArcGIS/zonal statistics. Regression using data in different polarizations, different combinations were executed by S-PLUS. Fig. 4 shows the change of HH, HV backscattering coefficients corresponding to the change of biomass in different scales. One plot was eliminated when we generated estimation equation of biomass using HH- and HV-polarization since it is wetland (Biomass ≈ 1 Mg/ha, several sub-plots were zero). Estimation equations of biomass are as followed,

$$B = -36.7224 - 1868.4845 \sigma^0_{\text{HH}} + 9859.8924 \sigma^0_{\text{HV}} \quad R^2=0.7654, N=23 \quad (3)$$

Where B is Biomass (Mg/ha), σ^0_{HH} is corrected backscattering coefficient in HH-polarization, σ^0_{HV} is corrected backscattering coefficient in HV-polarization, $RSE=32.54$ Mg/ha.

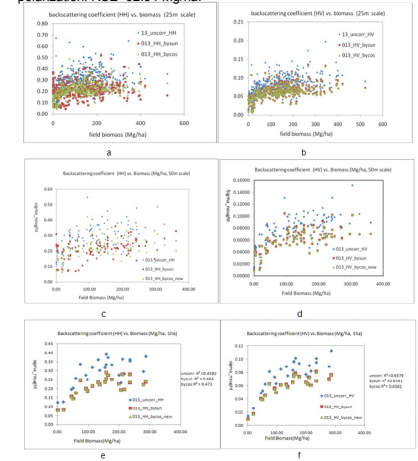


Fig. 4 (a, c and e show relation between backscattering and field biomass in different scales in HH-polarization; b, d and f show relations in HV polarization)

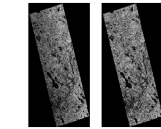


Fig. 5 (left: biomass estimated by uncorrected data; Right: biomass map by corrected data)

CONCLUSIONS

Some information needs to be noticed. First, R^2 of Biomass estimation by uncorrected backscattering coefficient is high, but for whole scene, it doesn't work. Secondly, corrected by different methods should be different in different scales, but nearly equal in 1 ha scale, there is no big difference between mean backscattering coefficient calculated by two methods in those 24 plots described in this paper. Thus we could make a conclusion: uniform correction equation without considering land cover types is enough when estimating biomass in 1 ha scale. More researches are needed to prove this. Thirdly, biomass retrieval by multi-polarizations is better than that by single polarization (HH and HV, respectively).

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